Swiss Contributions to War Surgery During the Great War

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Abstract

Background The role of neutral Switzerland during World War I is somewhat mysterious and its diplomatic history has never been fully disclosed. One of the activities might have determined its role: based on its relationship to the International Committee of the Red Cross, wounded multinational prisoners-of-war were interned in Swiss hospitals and Swiss physicians worked in a medical capacity in military hospitals on both sides of the front.

Questions/purposes The main question is whether the activities of the Swiss authorities reflected a charitable diplomatic role while retaining the country's traditional neutral stance. Supplementary practical questions included: How did Switzerland carry out the exchange of severely wounded prisoners of war? How did Swiss physicians function in the war zones? What were the medical objectives and the ultimate results of wartime surgery in Switzerland?

Methods This study is based on archival material from the Swiss Federal Archive in Bern (BAR) and original publications of Swiss and German physicians in professional journals. The search was performed manually in the

BAR evaluating the file “Landesverteidigung (national defense)” from 1848 to 2009. Original publications and journals were searched manually in the central libraries of Munich, Heidelberg, Zurich, and Bern.

Results The evaluation of Swiss diplomatic activities confirmed that Switzerland's charitable mission was aimed to enforce its neutral position and that Swiss authorities were able to efficiently manage the resulting problems. The engagement of Swiss surgeons in war surgery contributed to their experience and knowledge and yielded the development of many innovative medical devices and operating procedures, numerous of which are still known today.

Conclusion While maintaining its neutral position, Switzerland was able to deal with the practical problems while gaining innovative medical knowledge still valid today.

Introduction

Interest in wartime surgery has always increased at the onset of military conflicts. Heine, in 1866, published an article, “Bullet wounds of the lower extremities based on personal experience in the wars in Schleswig-Holstein” [36]. From the French perspective, “The treatment of fractures of the extremities caused by firearms” by Hénocque, appeared only slightly later during the War of 1871 [37].

Not surprisingly, the start of World War I heralded numerous journalistic reports on wartime surgery. In August 1914, the Munich-based medical weekly *Wochenschrift* published the first supplement for military doctors in the field. This series was inaugurated with an overview of “The general treatment of bullet wounds” by von Angerer [72]. Wartime surgery and orthopaedics

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experienced accelerated development during WWI: the number of severe injuries increased, thus providing the surgeons with more opportunities to observe a much greater diversity of injuries and treat and evaluate more patients than would ever have been encountered in peacetime. At the same time, the potential for surviving severe injuries increased owing to technical and scientific progress, and this in turn necessitated the development of subsequent rehabilitation methods [30, 62].

Although Switzerland was not actively involved in the war, Swiss war-related surgery during WWI led to medical advances. Switzerland was deeply interested in the training of Swiss physicians in wartime medicine, recognizing that their own services could be improved through knowledge obtained in the military hospitals. From the beginning of the war onward, Swiss doctors worked in Red Cross missions or were invited to work in foreign military hospitals at the second or third lines of treatment where they were able to gain experience in war surgery. Such medical missions were not a new occurrence: Swiss doctors were active during the War of 1870–1871 and during the Balkan Wars of 1912–1913 [30].

Medical practice in the military hospitals of the Swiss internment service was different than wartime surgery abroad. As a rule, the patients already had undergone surgery at least once as prisoners of war and patient followup care was guaranteed [27]. One can refer to this practice rather as secondary wartime surgery, which resembled peacetime trauma surgery. The primary orthopaedic aspects of wartime surgery in which Swiss doctors were involved included wound care, fractures and infections, pseudarthroses, and joint reconstructions and rehabilitation. Wartime surgery after World War I led to new methods of treatment and to the training of well-known physicians such as Hermann Matti, author of *Bone Fractures and their Treatment: A Textbook for Students* [47].

Swiss wartime surgery and orthopaedics during WWI have been examined only briefly [30, 62], with an emphasis on the activities of the International Committee of the Red Cross (ICRC) [23]. Because of Switzerland's neutral political status, unparalleled possibilities for advances in Swiss medicine were achieved. German, British, and French prisoners of war were interned in Switzerland, and Swiss physicians worked in a medical capacity in military hospitals on both sides of the front. Questions regarding the history of the *Swiss Internment of Prisoners of War* and activities of Swiss doctors in foreign military hospitals form the focus of this study.

The issues addressed are: (1) why Switzerland became involved charitably and how Switzerland maintained its political neutrality in light of its medical involvement; (2) how Switzerland performed the exchange of severely

wounded prisoners of war; (3) how Swiss physicians functioned in the war zones; and (4) the medical goals of wartime surgery in Switzerland.

Materials and Methods

The sources for this study were found mainly in the Swiss Federal Archive in Bern. The original publications of Swiss doctors are in large part housed in the Central Library in Zurich. Additional literature was obtained in the University libraries in Heidelberg and Munich. The search for sources was not limited directly to the war years however, and included a large number of earlier publications and developments. The search criteria for material were first, the historical development of the internment service, and second, wartime medicine in general. The search was conducted manually through the annuals of Swiss professional medical journals. The original medical publications were examined by hand and the applicable indications were categorized.

The publications examined were: *Archiv für Orthopaedische und Unfall-Chirurgie*, *Archiv für Orthopaedie, Mechanothérapie und Unfallchirurgie*, *Deutsche Interniertenzeitung*, *DGU-Mitteilungen und Nachrichten*, *Journal de Genève*, *Journal des Internés Français*, *Korrespondenzblatt für Schweizer Aerzte*, *Langenbecks Archiv für Chirurgie*, *Münchener Medizinische Wochenschrift*, *Neue Zürcher Zeitung und Schweizerisches Handelsblatt*, *La Revue hebdomadaire*, *Revue internationale de la Croix-Rouge*, *Revue médicale de la Suisse Romande*, *Sanitarisch-demographisches Wochenbulletin der Schweiz*, *Schweizerische Medizinische Wochenschrift*, *Schweizerische Rundschau für Medizin*, *Zeitschrift für Orthopaedie*, *Zeitschrift für Orthopaedische Chirurgie*, *Zentralblatt für Chirurgie*.

How Switzerland Became Involved in Wartime Surgery During WWI

Switzerland constantly strove to avoid becoming politically involved in the events of WWI. Throughout the entire war the country focused its energies instead on international involvement in the area of medicine. From the beginning of WWI Swiss physicians became active abroad in French, Austrian-Hungarian, and German military hospitals to apply their skills and to benefit from the experience of well-known surgeons like Theodor Kocher or Friedrich Steinmann. Their involvement was not entirely altruistic. The Swiss medical services attached great importance to bringing surgeons who had previously worked in Swiss military units up-to-date and to familiarizing them with

special methods and injuries encountered in military hospitals [35]. These missions, often organized by the Red Cross, were not new. There is ample evidence showing that Swiss doctors have long performed charitable and surgical duties in war zones. Chronicles such as those of Albert Burckhardt of Basel regarding the German-French War of 1871 recount which physicians worked in military hospitals in France and Germany [28]. He describes extensively his own work in the publication “Vier Monate bei einem Preussischen Feldlazareth waehrend des Krieges von 1870” (“Four months in a Prussian field hospital during the War of 1870”) [28]. August Socin from Vevey worked in the train-station military hospital in Karlsruhe in the German-French War of 1870–1871 [65]. Together with Albert Burckhardt-Merian, a well-known otolaryngologist from Basel, Socin worked in military hospitals in Ravenna and Verona during the Italian-Austrian War. Numerous Swiss physicians traveled to the conflicts in the Balkan states or in Libya in 1911 to 1913 and participated in Red Cross missions (Fig. 1), as did Hans Brun, who later ran the military hospital in Lucerne [30].

Swiss newspapers, archival material, and career resumes provide evidence that numerous Swiss physicians crossed the border in WWI to reach military hospitals and facilities. This occurred for the most part, however, in an unofficial capacity. Such placements thus came about at the start of the war either ‘on the quiet’ or it was made public that Swiss military installations existed on the enemy side of the front. As the war progressed, Swiss physicians became

active on both sides of the front and published their experiences in medical journals (22, 30) (Fig. 2).

How Switzerland Arranged Exchanges of Wounded Prisoners

Parallel to its medical missions, Switzerland organized, on the political level, an exchange of severely wounded prisoners of war via Switzerland and later enabled the accommodation of wounded war prisoners from German, English, and French prisoner-of-war camps in Switzerland (Fig. 3). Gustav Ador, president of the ICRC and a member of the Swiss National Council, together with the active cooperation of Pope Benedict XV, was able to engineer the Swiss internment of prisoners of war [4, 6, 71]. Between 1915 and 1918, approximately 70,000 prisoners of war thus entered Switzerland to receive medical treatment as a “Labour of Love” (Fig. 4) [2, 3, 23, 30, 40, 53, 56, 61, 70, 71].

Medical institutions initially were established in Lucerne and Fribourg for the exclusive purpose of serving war prisoners (Fig. 5). Hans Brun of Lucerne and Professor Clement of Fribourg [30] were named medical directors (Fig. 6). Both head physicians already had gained experience in military hospitals. Additional physicians who were recruited by the Swiss sanitary service included Hermann Matti of Bern, Carl Schlatter of Zurich (who later described what we now know as Osgood-Schlatter disease), Hans

Fig. 1 A Red Cross truck was used for transporting supplies to the line of fire and retrieving the wounded. (Reprinted from Reverdin A. [Activities of the Vaud-Geneva ambulance during the Greek-Turkish War.] *Correspondenzblatt für Schweizer Aerzte*. 1916; 46/11:374.)

Fig. 2 Notes on radiology in the field, Dr. Paul Narbel, Lausanne. The illustration shows a mobile radiology vehicle of the Red Cross in action. In the center of the picture a patient is lying on a stretcher. Left of the stretcher the mobile x-ray apparatus is seen. (Reprinted from Zollinger F, Ledergerber J. [Experiences in wartime surgery.] *Schweizerische Rundschau für Medizin* (Swiss Medical Journal, Vol. 16). 1916; 16. *Ambulanzwagen des Roten Kreuzes*.)

Hoessly, also of Zurich, Friedrich de Quervain of Basel (who described what we now call De Quervain's syndrome), and Charles Julliard of Geneva [31].

Prisoner-of-war internment gradually extended to include nearly all cantons of Switzerland (Fig. 7) with the exception of militarily sensitive areas [32]. The military physician Colonel Hauser headed the internment program

and was assisted by Colonel von der Mühl near the end of the war [33, 48]. Individual administrations were developed to regulate the organizational, disciplinary, and financial aspects of internment. The prisoners of war were housed in hotels and pensions (small hotels), which had been selected in consultation with the Swiss Hoteliers Association. The prisoners could be treated in existing

Fig. 3 This figure shows German soldiers getting off a Swiss train in Constance, Germany. They are accompanied by a German officer (Third man from the left side) (Reprinted from *Schweizer Illustrierte Zeitung* [Swiss Illustrated Journal.] 1915;15:192.)

Fig. 4 The symbolic personification of Switzerland as the figure of Helvetia, not as typically shown with a spear and shield, but with a loaf of bread and holding a child on her arm and illustrating the so called "Labour of Love" as mentioned by Swiss politicians. (Reprinted from Nagel E. [Switzerland's Labor of Love in the World War, *Pictures from Historic Times*.] Basel, Switzerland: Frobenius; 1916.)

Fig. 5 The 'A.S.A.' (Army Hospital) was located in Lucerne and owned by the Schweizerische Unfallversicherung (SUVA). It was rented to the Swiss authorities to establish a hospital for the interned prisoners of war. The building is still owned by the SUVA and is its headquarters. (Reprinted from Department of Prisoners of War of the Royal German Embassy in Bern. [The German Wartime Guest in Switzerland: A Memorandum of the Hospitalization of German Civilian and War Prisoners.] Munich, Germany, Piper; 1917.)

Fig. 6 The photo was taken during the visit of Prince Alfons of Bavaria in the A.S.A. in Lucerne. It shows his Ambassador von Boehm (second from right). He is accompanied by Dr. Brun, head of the hospital (fourth from left). The photograph also shows one of the wounded prisoners of war on crutches next to the ambassador. (Reprinted from *Deutsche Internierten Zeitung* [German Prisoner of War Newspaper.] 1917;35.)

Swiss hospitals and in Swiss sanatoria and spas. In addition, individual local treatment centers were established (Fig. 8). The largest were the prisoner of war hospitals in Lucerne and Fribourg, which admitted prisoners of war exclusively [30]. The selection of the prisoners in question was conducted by selection committees comprised of Swiss

Abfahrt eines Interniertenzuges auf dem Hauptbahnhof Zürich.

Fig. 7 This photo shows the departure of the prisoner-of-war train from Zurich's main train station. (Reprinted from Nagel E. [*Switzerland's Labor of Love in the World Wars, Pictures from Historic Times.*] Basel, Switzerland: Frobenius; 1916.)

Schönenberg.

Fig. 8 French prisoners of war were interned in Schoenenberg, Switzerland. The soldiers are shown during their physiotherapy. On the left one of the men is strengthening his right arm, by holding a handle that is combined with an armrest. The next soldier from the left is pulling a rope with his right arm. The rope is guided over a deflection pulley and on the end there is a weight that is lifted to strengthen his arm. The next two men are sitting on chairs and have leg injuries, but the type of therapy that they are using is unclear. They men are accompanied by a Swiss army officer, who is the fifth man from the left side and a male nurse, on the right side of the picture, wearing a brassard of the red cross. He is giving a massage to the lower limb of one of the soldiers. (Reprinted from Hélène P. [*Album of Prisoners of War in Switzerland.*] Switzerland, Geneva: Roger; 1917.)

physicians who traveled to the war camps in Germany, France, and Great Britain and examined the patients. After selection, the patients were transported by train to Constance or Lyon, where they underwent final screening [7, 30].

Once the prisoners had arrived in Switzerland, they fell under the jurisdiction of the Swiss medical services which did not supervise the soldiers around the clock but instead obliged them to adhere to an honor code and relied on the disciplinary presence of the soldiers' superiors [20, 25, 30, 64]. The prisoners were divided among different regions of internment in Switzerland according to nationality. These internment regions frequently were altered during the war. Generally German prisoners were located principally in central Switzerland, French prisoners for the most part in a French-speaking region of Switzerland (Fig. 9), and the British prisoners in the area surrounding Bern [31–33]. In addition to medical care in the form of operations, massages, and various courses of treatment, workplaces, leisure time activities (Fig. 10), and visits from relatives were organized.

The Swiss ambassador in Paris informed the Swiss Political Division on April 29, 1918, that the American government intended to appeal to Switzerland regarding the internment of sick and wounded American prisoners of war. Additionally, the United States wanted to establish a unit in Switzerland to treat American soldiers who were so severely wounded that they could not be transported home [8, 33]. The United States proposed sending a medical committee to Switzerland to cooperate with the Swiss Red Cross and other support services in helping American soldiers who either needed to be treated in Switzerland or

REGION MONTANA-VALAIS

Les Internés de Guerre

Martigny. — Arrivée des Internés français.

Fig. 9 The arrival of French prisoners of war at Martigny in Valais is shown. The soldiers are accompanied by a marching band, while the whole city is decorated with flags from Switzerland and France. The procession is watched by many civilians. (Reprinted from Hélène P. [*Album of Prisoners of War in Switzerland.*] Geneva, Switzerland: Roger; 1917.)

were arriving as prisoners of war from Germany [9]. The American ambassador in Bern, Pleasant A. Stovall, wrote to the head of the Swiss Political Division on May 9 stating that the United States wished to negotiate with the German government with respect to the imprisonment or repatriation of American prisoners of war [10]. Consequently, a conference was convened in Bern, Switzerland, between September 23 and November 11, 1918 [11]. The resulting agreement regulated the treatment of American and German prisoners of war, provisions for their repatriation and internment, and the release of medical personnel and procedure regarding restrained civilians [12]. The agreement never completely took effect and was suspended with the ceasefire of November 11, 1918 [17].

Following the ceasefire of Compiègne on November 11, 1918, the prisoner-of-war status for French, Belgian, and English prisoners ended immediately [5, 38, 51]. German prisoners however, retained their prisoner-of-war status until further notice [13]. The French were told that the ceasefire terminated previous related agreements [14]. With respect to the Belgian prisoners, Article 10 of the ceasefire agreements also was taken into consideration, however German prisoners in Belgian imprisonment were repatriated according to the earlier agreement for health reasons [16]. Owing to the existing internment arrangements, there was no longer hope that the German prisoners would be repatriated [71]. Pope Benedict XV, however, came to the aid for the German prisoners of war [50]. The English gave their approval in November 1918 to repatriate the prisoners who had come to Switzerland from English prisoner of war camps. Repatriation was scheduled for July 14, 1918, on the basis of the Hague Agreement. As this did not occur,

repatriation was performed “as an act of grace as such prisoners are not entitled to that privilege under armistice” [15]. France agreed in April 1919, to repatriate German prisoners who had been wounded or had tuberculosis [18]. A telegraphic order from Paris in July 1919, gave the permission to release German prisoners if they were in the condition to be transported [19]. Internment of all foreign nationals was completed by October 31st, 1919 [21].

Swiss Physicians in War Zones

An examination of the military hospitals close to the front in which Swiss physicians worked reveals a different kind of medical practice. Friedrich “Fritz” Steinmann (1872–1932), the developer of the eponymous pin [66, 75], from Bern observed operations while visiting German military hospitals in Constance in September 1914 [67]. At the end of September 1914 he traveled to the front in northern France and visited base and reserve military hospitals belonging to the German western army [68]. He was offered a position as director and head surgeon of a 2000-bed Austrian base hospital in the spring of 1915. Consequently, from mid-May to mid-June 1915, Steinmann served as the director of the surgical unit in Bielitz and was responsible for 200 beds. He operated with the Swiss doctors Ledergerber and Zollinger [68]. The three physicians published accounts of their experiences in numerous issues of the *Correspondenzblatt für Schweizer Aerzte*. Particularly interesting are their experiences with wound healing and healing of fractures using Steinmann’s pin traction technique (Fig. 11). Friedrich Steinmann already had introduced this surgical method in 1907 [66, 75] and used it on a large scale in the military hospitals [66]. In the beginning of their mission Steinmann,

Fig. 10 German prisoners of war are shown performing physical exercises. The soldier in the center of the picture is missing his left leg and is jumping over a rope. (Reprinted from *Deutsche Internierten Zeitung* [German Prisoner of War Newspaper.] 1917;16.)

Abb. 342. Extensionsnagel im Tibiakopf nach Steinmann.

Fig. 11 The drawing shows a traction pin in a tibial head, according to Steinmann. (Reprinted from Matti H. *Die Knochenbrüche und ihre Behandlung. Ein Lehrbuch für Studierende und Aerzte. Vol. I. Die Allgemeine Lehre von den Knochenbrüchen und ihre Behandlung.* Berlin, Germany: Julius Springer, 1918.)

Ledergerber, and Zollinger treated patients in the Austrian hospitals at Bielitz and Dzieditz who arrived in May and June 1915 directly from the trenches of battles in the Carpathian Mountains and the breakthrough on the Dunajec. Later the patients came from offensives in Russia and Poland and reached the rear military hospitals after a 1 to 3-day journey from the front by train [43]. The farther away the front moved from the military hospitals, the older the wound; in some patients this was as much as 1 year [43].

The Goals of Medical Care of Prisoners of War in Switzerland

Medical treatment in Switzerland differed from care at medical hospitals near the front. From surgical and orthopaedic points of view, the injuries of the patients transported to Switzerland generally no longer were acute, had been treated surgically previously, or had healed improperly. The most frequently performed treatments therefore dealt with the care of soft tissue wounds, fractures, nonunions and pseudarthroses, or damaged joints. Aftercare of postoperative patients was ensured by means of orthopaedic devices, which generally were built by prisoners specifically for the patients (Figs. 12–14).

Soft Tissue Wound Care

Ferdinand Sauerbruch commented, “the more thorough and careful the surgical work in the field, the easier the work at home” [60]. To achieve this goal, the entire area of the wound had to be exposed and cleansed and the injured

Figur 16.

Fig. 12 The illustration shows a wagon wheel converted into a device that allowed rotary motion of the arm. (Reprinted from Hoessly H. *Orthopedic Improvisations of our Clinic* [*Die Orthopaedischen Improvisationen unserer Anstalt*.] *Correspondenzblatt für Schweizer Aerzte*. 1916;46.)

Fig. 3.

Fig. 13 The sketch shows a device used to strengthen the leg muscles. A pulley block was fitted with a weight which was raised by the patient by an upward movement of the leg. (Reprinted from Hug OA. [Orthopedic Improvisations for War Wounded.] *Correspondenzblatt für Schweizer Aerzte*. 1917; 47/21: Supplement.)

Fig. 22.

Fig. 14 The sketch shows a device for strengthening arm and shoulder muscles. The patient stands in front of the device, and with his arms moves wooden bars to which weights are attached. (Reprinted from Hug OA. [Orthopedic Improvisations for War Wounded.] *Correspondenzblatt für Schweizer Aerzte*. 1917; 47/21: Supplement.)

limbs adequately immobilized (Fig. 15). This practice was combined with antiseptic treatment [46].

Ledergerber and Zollinger inserted drain tubes in the case of all infectious wounds [42]. The tubes were made mainly of thick rubber or glass which had the advantage of preventing premature wound closure. When drain tubes could not be inserted into the deepest part of the wound, gauze strips sterilized in a saline solution were applied to the wound, thus promoting drainage by capillary action [42]. In the event that no drain tubes could be inserted, for example, in the torso, drainage with suction cups, water irrigation of the wound based on the Carrel method [24], or Weiler's siphon technique [74] were used.

French military hospitals often used drainage systems, which included Carrel's suction treatment [29]. The Carrel-Dakin wound sterilization system was simple. Multiple rubber, glass, or silver tubes with a 6-mm diameter and approximately 33-mm length were inserted into an open wound. The number of tubes depended on the size of the wound. Cornioley inserted up to 12 tubes [29]. The tubes were first fixed with gauze compresses. The tube port was made approximately 1 m above the bed and a 9-mm diameter tube was attached to the connective joints. Enough pressure therefore was generated to enable irrigation of the wound with the sterile solution [29].

Fig. 15 The photograph shows a French soldier with a stirrup plaster cast for stabilizing the shoulder. This allowed free movement in the case of extensive shoulder injury. (Reprinted from Pettavel CA, [Experiences in Wartime surgery in a Red Cross Hospital in Lyon.] *Correspondenzblatt für Schweizer Aerzte*. 1916; 46/11: Supplement.)

Friedrich Steinmann and Otto Bernhard [24] concentrated on the healing effects of air and oxygen on wounds (Figs. 16 and 17). In their opinion, it was necessary to keep the wounds open to prevent development of anaerobic bacteria. The effects of this method could be enhanced further when combined with a drainage system and a constant supply of oxygen. Steinmann set up a “Luftstation” (oxygen chamber) in his base hospital for this purpose:

“An air pump and air vessel driven by a 3-horse-powered motor are set up in an adjacent room. The air pressure is channeled through an iron pipe into the infirmary and all the way around the wall of the room. Branching off of the main pipe are finger-sized tubes leading to each of the 20 beds arranged against the walls. A small spigot is attached to mouth of each individual tube. A rubber hose, which joins with a thin rubber catheter or a thin rubber tube having an interior diameter of 3 mm, is fixed to these small tubes” [69].

Fracture Care

After treatment of the wound, the surgeons dealt with the length and alignment of the fracture, generally with the aid of a radiograph. Three to four hundred patients often arrived at the military hospitals in a short time. The patients had to wait for radiographs and their fractures were merely splinted during this time. A specific rule in the treatment of bone fractures was that limb length had to be maintained.

Fig. 16 German soldiers and officers are shown during solar radiation treatment in the Solar Clinic of Bad Dürkheim located in the Black Forest region in Germany. The soldiers exposed their wounded limbs or body parts to the sunlight. (Reprinted from Nagel E. [Switzerland's Labor of Love in the World War, *Pictures from Historic Times*.] Basel, Switzerland: Frobenius; 1916.)

Fig. 39. Licht-Luftbehandlung der Wunden im Militärbarackenspital Bielitz.

Fig. 17 The photograph shows light and air treatment of wounds in Bielitz military hospital. (Reprinted from Steinmann F. [Experiences in Wartime Surgery regarding Gunshot Wounds of the Extremities.] *Correspondenzblatt für Schweizer Aerzte*. 1916; 66/42: 1359–1404.)

This was accomplished by removing muscle tension by means of a semiflexed positioning [45].

Albert Reverdin of Geneva recommended slight traction to treat limb injuries [58]. Steinmann specifically advocated skeletal pin traction, which he introduced to the barracks hospital in Bielitz from May to June 1915 [41]. He also believed “bloodless” tractions with adhesive bandages, should be used rather than skeletal traction unless the former proved ineffective [67]. Adhesive bandage traction initially was used to stretch the skin and only when the traction had reached its elastic limits did the muscles and bones move. However, as the war progressed Leukoplast® (an elastic material manufactured by the Beiersdorf Company, Hamburg, Germany) became scarce and cheap substitute bandages did not adhere sufficiently to apply traction [45].

During their stay, Ledergerber and Zollinger had the opportunity to familiarize themselves with various traction techniques. The most important applications in the Austrian military hospitals involved adhesive bandage traction according to Georg Bardenheuer [1] (Fig. 18) as modified by Vatroslav Florschütz [44, 52], and the pin traction introduced by Steinmann in Bielitz [41]. Ledergerber and Zollinger [41] later applied traction in all fractures with more severe comminution, reporting a total of 300 pin tractions. The pins were composed of 3-mm to 3.5-mm nonnickel-plated steel wire on which both ends had been cut into flattened points. The pins were produced in the

Abb. 287. Extension einer Oberschenkelfraktur durch kombinierte Quer- und Längszüge bei Verschiebung des oberen Fragmentes nach außen, des unteren Fragmentes nach innen, nach Bardenheuer. Die Fraktur liegt zwischen den Querszügen b und c.

Fig. 18 The drawing shows the reduction of a fracture of the upper thigh by means of combined transverse and longitudinal traction, shifting the upper fragment medialward and the lower fragment lateralward, according to Bardenheuer. The fracture lies between transverse tractions b and c. (Reprinted from Matti H. *Die Knochenbrüche und ihre Behandlung. Ein Lehrbuch für Studierende und Aerzte*. Vol. I. *Die Allgemeine Lehre von den Knochenbrüchen und ihre Behandlung*. Berlin, Germany: Julius Springer, 1918.)

hospital metalworking shop. Steinmann believed it important not to insert the pins in or near the fracture site owing to the danger caused by dislodging or inflammation at the site [41]. Ledergerber and Zollinger suggested pins should be inserted outside a fracture hematoma or infected area but not within the medullary cavity, the joint capsule, or the joint spaces [44]. They therefore used the upper shinbone as a pin site in 35% of cases [44].

A leg that had been operated on was splinted in a semiflexed position for 1 to 2 days to allow the bone to become accustomed to the foreign body. A weight subsequently was attached to the leg [41]. The semiflexed position of the leg, with a slightly elevated thigh and the calf nearly horizontal, was achieved with the aid of pillows placed beneath. A hanger was attached to the ends of the pins and by means of a wire or a strong cord threaded over a pulley attached to a 1.80-m board screwed onto the lower end of the bed, connected to the weight. The sole of the foot was secured at a right angle to the ankle to this wire or cord, which pulled sharply upward against the end of the bed, to prevent a plantar flexed position. Longitudinal traction alone frequently did not suffice in aligning the fragments, in which case additional medial or lateral traction was applied through broad bandages stiffened by cardboard to prevent the bandages from bunching together [44].

The results of the experiments conducted by Zollinger and Ledergerber suggested most patients experienced 6 cm to 8 cm shortening with a maximum of 19 cm shortening. The fact that pin traction could be performed only in a stable hospital was problematic for war surgery. Treatment was time intensive and the patients could not be moved during the traction procedure [41].

Fig. 19. Schmetterlingsfraktur an der Tibia.

Fig. 19 This sketch shows a butterfly fracture of the tibia. The bone was fractured by a bullet wound. (Reprinted from Steinmann F. [Experiences in Wartime Surgery regarding Gunshot Wounds of the Extremities.] *Correspondenzblatt für Schweizer Aerzte*. 1916; 66/42: 1359–1404.)

Steinmann used radiographs to document the numerous cases in the military hospitals in which he observed the effect of bullet wounds on bones [Fig. 19]. He also analyzed a bullet's explosive effect on impact with bone [69]. He observed distinctive injuries from lead bullets and the new type of jacketed bullets: the impact of jacketed bullets was so strong that the bone could break even when the trajectory was in proximity to the bone. In addition, these bullets caused extensive comminution with extraordinarily long splinters from the long bones [68, 69].

Pseudarthroses

An anthology describing the experiences gathered in prisoner of war camps was published by Hans Brun, Hans Hoessly, and Otto Veraguth in 1918 and 1919 [26, 27] and by Cornioley [29]. Brun, the director of the military institutions, chronicled in detail his experiences in the treatment of pseudarthrosis and further described individual cases in which a histologic study of the injured bone section could be performed, documented, and presented [27].

In most patients, the area of pseudarthrosis was surgically removed. Subsequently, fusion of fragments was attempted by means of a bone suture or bridging via bolting

or screwing together a bone graft from the shinbone, or via the use of metallic surgical plates [27]. Healing of the injury did not always meet the desired expectations. Brun concluded that the wartime pseudarthroses he treated represented special forms that did not occur in peacetime. The poor clinical condition of the patients Brun encountered in Lucerne was influenced by the damage to overall health resulting from the injury through loss of blood, infection accompanied by fever, emaciation of the body owing to prolonged ulceration, and poor healing during the months of internment. Another problem emerged in the increasingly customary use of traction in which the bone ends were distracted, increasing the risk of nonunion.

Brun furthermore described problems in the treatment of wounds [27]. Overly frequent changes of dressings and rinsing and draining of abscesses disturbed the stability of the fixation. The goal of wartime pseudarthrosis surgery thus was to achieve “the unobstructed alignment of the bone surfaces” [27] and achievement of stability and resilience after treatment.

Damaged Joints

Joint fractures represent a unique area of wartime surgery. Professor Charles Julliard from Geneva studied these injuries while serving as head of Hôpital 112 in Lyon [39]. He observed that approximately 1/3 of injuries to the limbs involved the knee. Charles Perrier [55] and H. Vulliet [73] realized these were severe injuries, as the surface of the knee was extremely large and prone to bacterial attack. Alfred Matthey proposed all knee injuries should be considered infected and treated accordingly [34]. This could prevent slight infections from being overlooked.

The treatment entailed opening the joint by means of arthrotomy and inserting one or more drains [34]. In case arthrotomy proved insufficient, resection was performed. This included constant rinsing with a sterile saline solution to wash out pus, cleansing of the wound, and removal of foreign bodies and necrotic bone fragments. The wound and joint cavity were cleansed and, in the acute phase, tamponaded with moist bandages (eg, sterile gauze or gauze which had been soaked in iodoform or hydrogen peroxide). The wound was not closed, but treated as an open wound when judged necessary (Fig. 20) [34, 63]. After resection, Reverdin and Grounauer applied modest traction to the injured limb and, in addition to drainage, maintained constant rinsing of the wound with a sterile saline solution [34, 58]. In the event that there still was no improvement and the infection persisted despite all of the measures taken, an amputation was performed [34].

Roux suggested that a resection be performed for all joints, as this improved the condition of the wound better

Fig. 5.

Mit Aluminiumschiene armierter Gipsbrückenverband; Osteomyelitis nach Schußfraktur, operiert.

Fig. 20 A plaster bridge bandage, reinforced with an aluminum splint is shown. The patient had osteomyelitis following a bullet wound fracture and underwent surgery. (Reprinted from Matti H. [Experiences and observations in Wartime Surgery.] *Correspondenzblatt für Schweizer Aerzte* 1915; 45/25: Supplement.)

than with arthrotomy [59]. However, if there still was no improvement or an opening of the joint seemed unavoidable, an arthrotomy still could be used [59]. Vulliet expressed a similar opinion. He recommended a wide opening on the knee and resection of the moving surface of the joint followed by suture of the soft tissues. He regarded arthrotomy as insufficient although he considered resection a less than optimal solution, as the joint was swimming in pus and the infection could spread further through such an intervention [73].

Another concern regarding knee injuries was that the fractures often were not limited to the knee. Grounauer and Matthey [34] and Reinbold [57] observed cases in which the tibia was also involved, and in young patients the growth plates. Infection consequently spread extensively in the area of the fracture.

In less severe cases, the injuries frequently healed uneventfully. The more severe cases often ended with ankylosis or markedly limited function, if not amputation [39]. The result of treatment was at best “*la récupération des mouvements articulaires*” (“recovery of joint motion”) [57], and if this was not possible, one could hope for a controlled ankylosis in a functional position. In worse cases, the patient ended up with a pseudarthrosis [57].

Discussion

The role of Switzerland during World War I is somewhat mysterious and still not fully disclosed. Its engagement with the ICRC, however, and its activity with the initiative

of the internment of wounded soldiers from different nationalities in Swiss hospitals were clearly aimed at preserving its neutral position. The question of (1) why Switzerland became involved charitably and how it maintained its political neutrality are easy to answer: in light of its medical involvement, the charitable mission was probably one of the main activities guaranteeing its political status. The questions of (2) how Switzerland performed the exchange of severely wounded prisoners of war; (3) how Swiss physicians functioned in the war zones; and (4) the medical goals of wartime surgery in Switzerland can be answered based on the traditional behavior and current practice published in medical journals.

This report is limited in numerous ways. First, reconstructing the course of prisoner of war internment and its administrative realization was achieved based on the literature and archive reports. However, the archive reports and communications originate exclusively from Swiss sources; no German sources could be found and archive searches in France and the Vatican were not feasible. Second, the description of the medical activities of Swiss physicians was one-sided. The original works were restricted to presentation of the methods of treatment and surgery accompanied by examples from actual medical practice. The organizational procedure and accomplishments of the Red Cross missions and daily life in the military hospitals cannot be described in detail, as the available sources do not allow for any conclusions to be drawn. Third, the long-term results and rates of success of the various treatments are unknown. The final disposition and handling of the maimed and unemployable war veterans were dealt with by the home countries. Treatment of wounded soldiers in the military hospitals ended for the Swiss physicians at repatriation of the prisoners of war. This vital aspect of war surgery—the rehabilitation of the wounded into society—was mentioned repeatedly in the physicians’ reports as no longer being relevant for the Swiss wartime doctors [31].

The question regarding why Switzerland became involved charitably is perhaps central to Swiss contributions to war surgery and it is intriguing to explore how Switzerland maintained its political neutrality in light of its medical involvement. Favre’s reports on internment [31–33] and Panzera’s essay [53] show the Swiss were intent on providing the infrastructure and medical specialization expertise. An analysis of the archive sources clearly shows that the motivation for establishment of prisoner of war internment did not entirely originate with the Swiss, but was more of an international occurrence [2–22]. This is evident as well in the exchange of wounded and sick prisoners of war in that Switzerland was dependent on the help of the warring countries, which had to transport the wounded to the borders. Favre’s reports support this fact

[31–33]. The objectives of Swiss wartime surgery were based on Switzerland's humanitarian interests according to Favre [31–33]. The country did not want to remain impassive but instead actively offered help [31–33]. The Swiss medical service therefore could at the same improve as a consequence of the knowledge obtained in the military hospitals. This knowledge was discussed at various conferences [34, 39, 49, 57]. Switzerland maintained its neutrality by being active on both sides of the front in the care and exchange of patients, internment procedures, and repatriation [2–11, 30]. Therefore it was in Switzerland's interest to use the multilingual skills of the physicians by placing them in foreign military hospitals. This can be deduced from the sites at which the physicians were active; partly German or Austro-Hungarian and partly French military hospitals [41, 47, 54, 55].

The question of how Switzerland carried out the exchange of severely wounded prisoners of war is instrumental to examining the efforts of the ICRC under President Gustav Ador, who was also a member of the Swiss National Council. The idea of prisoner exchange was supported by Pope Benedict XV [4, 5, 71]. Swiss authorities enabled the accommodation of wounded war prisoners from German, English, and French prisoner of war camps in Switzerland [2, 3, 23, 30, 31, 40, 53, 56, 61, 71]. The military physician Colonel Hauser headed the internment program and was assisted by Colonel von der Mühl near the end of the war [33, 48]. The prisoners could be treated in existing Swiss hospitals and in Swiss sanatoria and spas. In addition, individual local treatment centers were established. The largest were the prisoner of war hospitals in Lucerne and Fribourg, which admitted prisoners of war exclusively [30]. The selection of the prisoners in question was conducted by selection committees comprised of Swiss physicians who traveled to the war camps in Germany, France, and Great Britain and examined the patients [7, 30]. The prisoners were divided among different regions of internment in Switzerland according to nationality. These internment regions were altered frequently during the war. Generally German prisoners were located principally in central Switzerland, French prisoners for the most part in a French-speaking region of Switzerland, and the British prisoners in the area surrounding Bern [31–33].

The third question how Swiss physicians functioned in the war zones is answered by analyzing the articles of Swiss doctors in professional journals. On the German side there were well-known Swiss doctors like Friedrich "Fritz" Steinmann (1872–1932), the developer of the Steinmann pin [66, 75] from Berne. He visited several hospitals in the war zones that were run by the German and the Austro-Hungarian army [67, 68]. He operated with the Swiss doctors Josef Ledergerber and Friedrich Zollinger [68]. The three physicians published accounts of their

experiences in numerous issues of the *Correspondenzblatt für Schweizer Aerzte*. Particularly interesting are their experiences with wound healing and healing of fractures using Steinmann's pin traction technique. Hermann Matti also worked in German army hospitals [46]. On the other side of the front, Professor Charles Julliard from Geneva studied these injuries while serving as head of Hôpital 112 in Lyon [39]. Swiss surgeons were able to learn and work with the newly developed drainage systems, which included Carrel's suction treatment [29]. Dr. Cornioley from Geneva was working with this technique in the army hospital in Val de Grâce from 1915 to 1917 [29].

The medical goals of wartime surgery were varied, but among the first concerns of Swiss doctors was the healing of wounds. This often occurred in combination with infection and was a part of virtually every publication on wartime surgery cited in this article. Various types of wounds and possible variations of wound treatment were extensively observed [29, 41–46, 54, 57, 60, 66–69, 72, 73]. At the onset of an infection, it became clear that conservative treatment could not be continued, but rather required special measures such as arthrotomy, resection, drainage, or oxygen treatment [29, 43, 46]. Another primary concern was fractures. The opinions of the Swiss physicians overlapped on one point. Fixation was the main focus of further treatment. Nonetheless, different methods prevailed based on the military hospital and available materials. In addition to débridements of open fractures and bullet wounds, traction was frequently used. Traction could be applied in a "bloodless" (adhesive bandages) or "bloody" (with pins) manner, but the treatment could not be performed by every physician: Steinmann pin traction could be used by Steinmann, Ledergerber, and Zollinger [41–45, 66–69]. Plaster or bloodless traction, however, were performed by other physicians [26, 46]. The treatment of pseudarthrosis was not a direct obligation of wartime surgery in the military hospitals close to the front. Pseudarthroses occurred as a complication of infection, inadequately treated fractures, or simply from a severe injury [27, 39, 57]. The conclusion that an open joint injury was always infected [34] and the frequently extensive nature of the injury [57] often led to limitation of function or pseudarthroses [27, 39, 57]. Treatment thus generally was operative in combination with drainage. Reverdin and Grounauer showed that it was not always possible to retain the joint [34, 57].

The charitable mission of Switzerland was one of the main activities, guaranteeing its political neutrality. The exchange of severely wounded prisoners was possible with the help of the ICRC, the support of Pope Benedict XV, and with the acceptance of the Swiss authorities. Swiss physicians visited and worked in numerous hospitals in the various war zones, collected experiences, developed new methods, and published them in medical journals. The

experienced advanced treatments, not only on wartime injuries, but those experience in peacetime as well.

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